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(19) THE PATENT OFFICE LONDON

(54) MANUFACTURING A HARDENED STEEL ARTICLE

(71) We, NORRBOTTENS JÄRNVERK A.B., a Swedish Body Corporate of S—951 00 Luleå, Sweden, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

The invention relates to a method of manufacturing a hardened steel article, particularly one with small wall thickness and good dimensional trueness.

For producing hardened and possibly tempered thin details, for example of thin sheet metal, preferably below 3 mm, with good dimensional trueness, heretofore the detail after having been formed in a conventional manner was taken out of the forming apparatus, positioned in a holder to prevent subsequent distortion, and thereafter hardened and, possibly, tempered. This procedure is complicated and involves high requirements on the hardenability of the steel used.

The present invention provides a method of manufacturing a hardened steel article, in which a blank of hardenable steel is heated to hardening temperature and thereafter placed in a forming apparatus in which the blank is formed to the desired final shape by being subjected to substantial deformation and simultaneous rapid cooling, such that a martensitic and/or bainitic structure is obtained while the blank remains in the forming apparatus, which serves as a gauge for preventing distortion of the blank.

Preferably a blank of uniform thickness is used, and preferably the thickness of the formed article at any point differs from the thickness of the blank by no more than 25% of the thickness of the blank.

The steel utilized as starting material is preferably a boron-alloyed carbon steel or carbon manganese steel. In order to obtain the desired combination of hardness and toughness which may render the tempering step unnecessary, a steel may be used which contains, by weight, less than 0.4% carbon, silicon in an amount depending on the steel production method but in general being insignificant, 0.5 to 2.0% manganese, at maximum 0.05% phosphorus and at maximum 0.05 sulphur, 0.1 to 0.5% chromium and/or 0.05 to 0.5% molybdenum, up to 0.1% titanium, 0.0005 to 0.01% boron, up to a total of 0.1% aluminium and possibly insignificant low contents of copper and nickel, possibly in contents of up to 0.2% each.

Preferably the steel contains less than or equal to 0.25% (preferably 0.15 to 0.25%) carbon, silicon in an amount depending on the steel production method but in general being insignificant, 0.5 to 1.5% (preferably 0.7 to 1.5%) manganese, at maximum 0.03% phosphorus and at maximum 0.04% sulphur, 0.1 to 0.3% chromium and/or 0.05 to 0.5% molybdenum, 0.02 to 0.1% (preferably 0.02 to 0.05%) titanium, 0.0005 to 0.007% (preferably 0.0005 to 0.005%) boron, 0.03 to 0.1% (preferably 0.03 to 0.07%) aluminium, and possibly low insignificant contents of copper and nickel, possibly in contents of up to 0.2% each.

The steel is heated to hardening temperature, i.e. to a temperature above Ac_3 where the steel will be in austenitic state. The steel preferably is heated to a temperature between 775° C. and 1000° C.

The forming operation is preferably a pressing operation, but the method can also use other forming techniques, such as drop forging, extrusion and explosive forming.

In the preferred pressing operation the blank

is formed between two tools or against one tool by means of some pressure medium. It is desirable to apply a quick-operating press so designed that the position and speed of the tool(s) can be controlled during the entire process. It is, thus, desired that forming takes place in less than five seconds, preferably less than three seconds, so that forming is completed before the desired hardening structure is attained.

The forming and cooling operation is ideally to be carried out so rapidly that a fine-grain martensitic and/or bainitic structure is obtained. The necessary rapidity depends on the analysis of the steel, i.e. on its Continuous Cooling Transformation graph (CCT-graph). The rapid cooling preferably continues after deformation has been completed, with the pressed blank remaining in the forming device. Cooling of the pressed article may be effected indirectly by cooling parts of the forming device and/or directly by bringing the pressed blank into direct contact with some cooling medium. The tool or tools serves or serve as a gauge during the cooling operation, so that the final product obtained has good dimensional trueness.

By using the preferred steel it is possible to manufacture thin bearing sheet or shell structures with high strength. The combination of high strength and good tenacity permits the manufacture also of energy absorbing (i.e. shock absorbing) details. Hardened (untempered) sheet structures are intended especially for use in transport vehicles for parts which can be expected to have to take up shocks during collisions, primarily the bumpers, but also other body details. It may generally be said that vehicle parts which are exposed or for which there is a risk of becoming exposed to heavy shocks advantageously should be manufactured according to the invention by utilizing the preferred steel specified above.

It is a great advantage that the steel can be used in hardened state without subsequent tempering, because it reduces the heat treatment by one step and eliminates a source of dimensional inaccuracy. The resulting articles, moreover, are harder.

For achieving a full effect of the low boron content of 0.0005 to 0.01% the boron addition to the steel is to be made after the contents of titanium and aluminium indicated above have been added, so that oxygen and nitrogen are already bound when boron is being added. Boron steel is a weldable structural steel, which is given extremely high strength in combination with good toughness by a simple heat treatment. A yield point of greater than 120 kp/mm^2, with an elongation of about 10% at fracture, is not unusual. The relatively high hardness in combination with a good elongation after hardening provides the boron steel with very good shock-absorbing properties. With respect to its base analysis, the boron steel is a carbon manganese steel, which by a special metallurgical treatment and by alloying with boron has been given very good hardening properties. Owing to the boron addition, the steel after its hardening by water or oil quenching exhibits a fine-grain structure consisting of low-temperature bainite and tempered high-temperature martensite. It is by this structure that the boron steel shows its combination of hardness and toughness, in contrast to a steel not alloyed with boron, which after hardening exhibits a brittle hardening structure.

A boron-alloyed steel has, in addition to the aforesaid improvements in its mechanical properties, a much better penetration hardening capacity than a steel with the same base analysis without a boron addition.

The very high strength properties and the good shock-absorbing properties are obtained after the hardening. A suitable hardening temperature, between 775° C. and 1000° C., is 900° C. For wall thicknesses below 6 mm quenching in oil or salt water is recommended.

EXAMPLE.

Table 1 shows the results by way of strength values and hardnesses for six different steel analyses formed into hardened articles according to the invention having various wall thicknesses. The following values may conclusively be stated as guide values for the mechanical properties:

Hot rolled or cold rolled and annealed state:

δ_S kp/mm²	δ_B kp/mm²	δ_5 %
36–42	50–60	23–55

(δ_S = yield stress, δ_B = ultimate tensile strength, δ_5 = elongation at fracture).

Hardened state: The following guide values are obtained, depending somewhat on dimension and hardening medium:

δ_S kp/mm²	δ_B kp/mm²	δ_5 %	Hardness	Toughness
			HRC	KCU 0°C kp/cm²
120–150	150–170	8–12	45–50	5–10

(HRC = Rockwell 'C' hardness)
(KCU = impact energy, tested in accordance with ISO/R83).

With respect to their weldability, the boron-alloyed steels are to be judged after their base analysis, thus their carbon and manganese contents, because the structure attained in the heat-affected zone is not sensitive to hydrogen embrittlement. The boron steels listed in the Table, therefore, can easily be welded as normal high-strength structural steels.

When the boron steel is to be welded prior to the forming and hardening, the properties of the base material after hardening can be attained also in the welding joint by using special electrodes adapted to the boron steels.

TABLE 1

Examples of strength achieved after hardening

Charge	Thickness mm	Analysis									Strength				Hardening medium
		C %	Si %	Mn %	P %	S %	Cr %	Ti %	B %	Al %	0.2 Kp/mm²	B Kp/mm²	5 %	Hardness	
B 6959	6	0.24	0.37	0.94	0.030	0.019	0.197	0.040	0.0050	0.060	118 132	174 179	10 11	HB 470	10% saline solution
B 7000	6	0.23	0.31	0.95	0.022	0.018	0.154	0.036	0.0031	0.123	120	164	10	HV10 486	,,
B 7000	4	,,	,,	,,	,,	,,	,,	,,	,,	,,	145	167	—	HB 455	,,
B 8307	6	0.19	0.31	0.77	0.016	0.016	0.207	0.032	0.0029	0.046	112 114	155 156	11 11		,,
A 2197	4	0.19	0.23	0.77	0.024	0.024	0.195	0.030	0.0031	0.040	119 119	153 158	10 12		,,
B 6938	4	0.23	0.39	0.87	0.020	0.023	0.196	0.043	0.0034	0.069	102 96	143 134	8 8	HRC 42	Oil
B 8307	6	0.19	0.31	0.77	0.016	0.016	0.207	0.032	0.0029	0.046	85 88	96 110	9 9		,,
B 8500	1.75 1.75 1.75 1.5	0.24	0.27	0.79	0.016	0.019	0.18	0.040	0.0050	0.139	123 92	165 136	10 9	HV5 550 HV5 435 HV 400—450 HV 420—490	10% saline solution Oil Tool Tool

WHAT WE CLAIM IS:—

1. A method of manufacturing a hardened steel article, in which a blank of hardenable steel is heated to hardening temperature and thereafter placed in a forming apparatus in which the blank is formed to the desired final shape by being subjected to substantial deformation and simultaneous rapid cooling, such that a martensitic and/or bainitic structure is obtained while the blank remains in the forming apparatus, which serves as a gauge for preventing distortion of the blank.

2. A method as claimed in claim 1, in which the blank is heated to a temperature above AC_3.

3. A method as claimed in claim 2, in which the said temperature is between 775° C. and 1000° C.

4. A method as claimed in any of claims 1 to 3, in which deformation and cooling are carried out so rapidly that a fine-grain martensitic and/or bainitic structure is obtained.

5. A method as claimed in any of the preceding claims, in which forming is carried out between two tools, which are pressed together rapidly.

6. A method as claimed in any of claims 1 to 4, in which forming is carried out against one tool by means of a pressure medium.

7. A method as claimed in any of the preceding claims, in which the rapid cooling continues after deformation has been completed, the blank remaining in the forming apparatus.

8. A method as claimed in any of the preceding claims, in which cooling is effected by cooling parts of the forming apparatus.

9. A method as claimed in any of the preceding claims, in which cooling is effected by contacting the blank directly with a coolant.

10. A method as claimed in any of the preceding claims, in which the blank is of uniform thickness.

11. A method as claimed in claim 10, in which the thickness of the formed article at any point differs from the thickness of the blank by at most 25% of the thickness of the blank.

12. A method as claimed in any of the preceding claims, in which the hardenable steel contains, by weight, less than 0.4% carbon, 0.5 to 2.0% manganese, at maximum 0.05% phosphorus and at maximum 0.05% sulphur, 0.1 to 0.5% chromium and/or 0.05 to 0.5% molybdenum, up to 0.1% titanium, 0.0005 to 0.1% boron, and up to 0.1% aluminium; the balance being iron and impurities including silicon.

13. A method as claimed in claim 12, in which the steel contains, by weight less than or equal to 0.25% (preferably 0.15 to 0.25%) carbon, 0.5 to 1.5% (preferably 0.7 to 1.5%) manganese, at maximum 0.03% phosphorus and at maximum 0.04% sulphur, 0.1 to 0.3% chromium and/or 0.05 to 0.5% molybdenum, 0.02 to 0.1% (preferably 0.02 to 0.05%) titanium, 0.0005 to 0.007% (preferably 0.0005 to 0.005%) boron, and 0.03 to 0.1% (preferably 0.03 to 0.07%) aluminium.

14. A method of manufacturing a hardened steel article substantially as described herein with reference to the Example.

15. A hardened steel article manufactured by a method according to any of the preceding claims.

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